RATE OF FOOD CONSUMPTION OF
ACRIS CREPITANS BLANCHARDI HARPER
IN SOUTH-CENTRAL IOWA

An abstract of a Thesis by
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The problem. The relationship between food consumption and seasonal activity was not known for *Acris crepitans blanchardi* Harper, Blanchard's cricket frog, nor had the rate of food passage through the stomach of this species been calculated. This study determined these factors and calculated a yearly insect consumption figure for *Acris* in south-central Iowa.

Procedure. An analysis of the diet of *Acris* was correlated with various features of the frog's life cycle. A total of 340 frogs were captured from 5 April 1972 until 27 October 1972. Stomach contents of 218 frogs were analyzed. The remaining 122 cricket frogs were used to determine the rate of food passage from the stomach.

Findings. *Acris* were active from early April to late October. Juveniles first appeared in August, and by October were the same size as April specimens. Nearly all the items in the stomachs were arthropods. Insects contributed the largest percentage of numbers and volume followed by arachnids. Food items passed through the stomachs in approximately eight hours. *Acris* fill their stomachs three times daily.

Conclusions. A typical *Acris* consumes approximately 4,840 food items each year. Agricultural pests consumed included members from Aphididae, Cicadellidae, Curculionidae, Syrphidae, and Locustidae.

Recommendations. The techniques developed for determining the rate of food passage can be applied to studies of other anurans. Field cages should be used to reduce unnatural conditions.

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A Thesis

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by

Bruce Kenneth Johnson

August 1973

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INTRODUCTION

An understanding of food consumption is needed in order to evaluate the niche of any organism. No extensive analysis of the food habits of Blanchard's cricket frog, *Acris crepitans blanchardi* Harper, have been made even though the frog is abundant throughout the eastern United States. Previous studies of the food of cricket frogs have encompassed relatively short periods of time and were based on relatively small numbers of individuals. Garman (1892) was the first to make note of the food of *Acris*. He stated that the food consisted largely of aquatic insects, but Hartman (1906) reported that the stomach contents of seven *Acris gryllus* consisted of "ants, a caterpillar, lady-bugs, snapping beetles, a spider, one small crayfish, and small beetles unidentified" indicating a more terrestrial diet. The present study attempted to determine in part, whether the diet of these frogs in Iowa was more terrestrial or aquatic. The studies of Garman (1892) and Hartman (1906) failed to give dates of sacrifice and location of capture.

Jameson (1947) reported the stomach contents of 63 *A. crepitans* Baird and concluded that their diet consisted mainly of aquatic insects many of which were bottom dwellers. This study utilized 67 frogs captured in March and April in Kansas and 27 captured during October in Nebraska. The author did not explain why only 63 of the 94 frogs in the total sample were analyzed.

Gehlback and Collette (1959) reported that of eight *A. c. blanchardi* Harper specimens examined, "two contained carabids, two had pyralid larvae, and one each contained mirids and small spiders." Duellman and Schwartz (1958) briefly summarized the stomach contents of 36 *A. gryllus dorsalis* from Florida and found mostly beetles and ants in the stomachs of the frogs.

A comparison of literature from past studies of cricket frogs was difficult because of confusing taxonomic changes. Although Hartman (1906) reported the frogs in his study taken from Kansas as *Acris gryllus*, they were probably *A. crepitans*. Viosca (1923, from Dunn, 1938) stated that the genus *Acris* was composed of two species, *A. gryllus* and *A. crepitans*, and that *A. gryllus* was found from Georgia to Mississippi and to the gulf coast. *A. crepitans*, a northern species, was found from Connecticut westward through southern Michigan, southern Minnesota to Utah and south to Georgia and western Texas at altitudes up to 2000 feet (Breckenridge, 1944). Dunn (1938) stated that the range of *A. crepitans* extended westward to the Canadian Northwest. Where the two species occurred sympatrically in Louisiana, "*gryllus* was found in the uplands and *crepitans* in the lowlands" (Viosca, 1923; from Dunn, 1938). There was no question but that the frog used in this study was *A. c. blanchardi* Harper.

Concern over insecticide resistant insects placed further importance on understanding the part played by natural insect predators. Amphibia have often been exposed to pesticides applied directly to their habitat or as a result of runoff from treated agricultural lands, and these insecticides have been shown to be deleterious to frogs (see Ferguson and Gilbert, 1968; Sanders, 1970; and Kaiser and Dunham, 1972). Potential increases in pesticide resistant insects make it important to understand all the natural barriers to increases in insect populations. One source for the accumulation of chlorinated hydrocarbons in frogs is from insects (Sanders, 1970). It is necessary to know the food sources of frogs and other insectivores to successfully follow the concentrations of pesticides in food chains.

The importance of frogs and toads as potential natural controls on insect pests should not be underestimated. A compilation of estimated losses due to approximately 60 insect species in the United States in 1938 was set at $1,601,527,000 (Haeussler, 1952). Cope (1952) stated that the economic importance of frogs and toads was enhanced when insects constituted a major portion of their stomach contents; he cited _A. crepitans_ and _Bufo woodhousi_ as two representative species that consume prodigious numbers of insects. Cope (1952) also stressed the importance of seasonal variation in habitat conditions and insect frequencies as factors that influenced the diet of amphibians. Pack (1922) reported _B. woodhousi woodhousi_ eating sugar-beet web worms in Utah in August 1921. Each toad had between 24-40 worms in its stomach, and Pack felt the toads were helpful in regulating the insect outbreak. The present study attempted to determine whether cricket frogs were significant insect predators, and therefore, by conjecture, whether destruction of the frogs by any means might permit more rapid growth of insect populations.

In order to determine food consumption from stomach contents, it was necessary to determine the rate at which stomachs were filled and emptied. The rate of digestion of stomach contents varies from species to species of anurans. Frost (1932) found that food passed through the digestive tract of captive *Rana clamitans* in two to three days. Kirkland (1904) and Dickerson (1906) stated that toads emptied their stomachs four times daily. Smith and Bragg (1949) criticized this figure because the identity of the species of toad(s) was not reported. The latter workers found that *Bufo terrestris americanus*, *B. cognatus*, *B. compactilis*, and *B. woodhousi woodhousi* adults emptied their stomachs once each day and juveniles twice each day. Frost (1932) stated that digestion in toads and frogs was comparatively slow, and the time it took for food items to be digested varied with the amount of food accepted and the food item itself.

This study attempted to determine possible relationships between food consumption and various features of the frog's life cycle. These included the annual cycle of activity and hibernation, the cycle of growth and metamorphosis, and the reproductive cycle. Failure to correlate food consumption with these cycles has been a drawback of other studies of this species. Finally, this study developed an insect-consumption figure based on the preceeding objectives that can be used in calculating the effects of *Acris* on insect populations in south-central Iowa where large populations of the frog exist.

MATERIALS AND METHODS

Two collecting areas were selected for study near Des Moines, Iowa, on the basis of preliminary observations indicating large populations of cricket frogs, *Acris crepitans blanchardi* Harper. Area I was on the Burton Haglan farm ½ mile west, 2 miles south of Cumming, Warren Co., Iowa (SE¼, Sec. 29, T77N, R25W, PM5) and consisted of a one-acre, man-made pond surrounded by an alfalfa field. It was approximately 200 yards from a tree-lined intermittent stream. Emergent vegetation consisted mostly of cattails in the northern and southern ends of the pond; the floating vegetation, mostly *Chara* and *Potamogeton*, was found as far as 10 feet from the shoreline. The eastern and western shores of the pond were either covered with short grass or were barren of vegetation. A fence surrounding the pond prevented entrance of domestic livestock.

Area II was at the Drake University field station 1½ miles southeast of Winterset, Madison Co., Iowa (SE¼, Sec. 8, T75N, R28W, PM5). This site consisted of a permanent stream bordered by tall grass; it runs parallel to county road G-50 through an open valley which is surrounded by dense woodland.

At least 2 collections of frogs were made each month, except for October, for studies of stomach contents. All frogs used in the study (340) were captured at the two collecting areas by hand. All specimens used for analysis of stomach contents (218) were sacrificed within five minutes of capture by cephalic injection of 70% ethanol. Digestion was stopped by injection of 7% formalin into the body cavity, and the frogs were fixed in a normal resting position in 5% formalin.

Gross external measurements were taken the same day the specimens were sacrificed. Records were made of snout-vent length, tibiofibula length, sex, reproductive state of females, weight of stomach with contents, and weight of empty stomachs. Linear measurements were made using vernier calipers, and stomachs were weighed on a Mettler balance. Net weight of stomach contents was obtained for each frog by subtracting the weight of the blotted empty stomach from that of the blotted full stomach. Stomachs were blotted with absorbent paper towels, Chem-wipes, by placing the stomachs between folds of the towel and pressing firmly on the stomach for approximately five seconds. This process was repeated twice to ensure that no excess liquid was remaining on the stomachs. Stomach contents were catalogued and stored in 70% ethanol.

Reproductive state of females was determined by examining the ovaries and noting the relative size of the egg masses. Egg masses were grouped into four categories: very small, small, large, and very large. A very small egg mass was approximately 1 mm long and 1 mm wide and appeared as a white and yellow mass at the end of the oviduct on the dorsal wall of the body cavity. Small egg masses were larger than these but less than 4 mm long and 2 mm wide. Large egg masses were longer than 4 mm but less than 10 mm long and 5 mm wide and almost filled the body cavity. Very large egg masses completely filled the body cavity causing the body wall to become distended; these were as much as 16 mm long and 10 mm wide.

Contents of stomachs were divided into three categories: plant material, animal material, and inorganic debris. Animal material was identified to family whenever possible; this was often difficult because digestion frequently fragmented the food items. Particular attention was paid to identification of agricultural pests. Total weight of stomach contents was correlated with snout-vent length, reproductive state, and seasonal activity. Numbers of insects of each taxonomic group was also correlated with each of these variables as was relative volume of each type of insect per stomach. Insects were identified with the keys of Jacques (1947), Laffoon and Harris (1958), Scott (1961), Ross (1965), and Borror and White (1970).

In order to determine the importance of cricket frogs as consumers of different insect types, it was necessary to determine not only what insects were present in the frogs' stomachs at any one time but to also determine the number of times each frog emptied and refilled its stomach each day. Two methods were used to ascertain the rate of digestion and passage of food items from the stomach. In the first method, two insect free cages were placed on the shoreline of the area I farm pond so that approximately ¼ of the cage extended into the water with the remainder of the cage on dry land. One side of the cage faced an open area, one faced the water, and two sides were surrounded by tall grass. The cages (20 x 40 x 8 cm) had a wooden floor and two wooden slats on top for easy access. The sides were covered with one-sixteenth inch mesh aluminum screen. A similar control cage was placed eight feet from the experimental cage containing the frogs. Fifty-four _A_. _crepitans_ were placed in the experimental cage, and seven frogs were removed each hour, sacrificed, and preserved. An additional 24 frogs were sacrificed at time zero to determine whether or not these frogs had full stomachs and if the contents were identifiable. The stomach contents of each group were weighed, identified, and compared.

In order to determine whether continual feeding significantly affected the rate that food moved through stomachs, a second experiment was conducted, this in area II. A cage (60 x 180 x 75 cm) constructed of three-eighth inch galvanized wire screen and supported by wooden stakes was so placed that approximately one-third of it was in water, one-third on unvegetated gravel, and the remainder in vegetation consisting of grass. Small insects could crawl freely through the screen. Representative habitats were present within the cage to allow the frogs to forage and thermoregulate normally. Frogs used in this experiment were force-fed Drosophila melanogaster dyed with Kodack Opaque Red, a non-toxic, non-digestable compound. The flies were placed in the mouths of the frogs with a small pair of forceps. Preliminary experiments using techniques adapted from Throckmorton (1971) showed that the dyed flies could be seen in various parts of the intestinal tract after passage through the stomach. These frogs were allowed to consume other insects after they were fed the Drosophila. Frogs were sacrificed at hourly intervals, and the stomach contents were weighed and analyzed in the laboratory as in the previous experiment.

Results of the experiments and other raw data were analyzed statistically. Means, ranges, standard deviations, standard errors, and 95% confidence limits were obtained with the aid of a Monroe G990 calculator.

All frogs and insect specimens used in this study were tagged, numbered, and stored in the Drake University Research Collection where they are available for further study. Field catalogues and journals kept throughout the study are also available.

RESULTS

Annual activity cycle. In central Iowa, *Acris crepitans blanchardi* Harper were active from early in April until the end of October of 1972. The first specimens were captured on 5 April and the last on 27 October. Cricket frogs were first heard calling on 15 May and last heard on 25 July. Froglets were first observed on 1 August and several were captured; during the first week in August, the population of juvenile frogs in area I increased dramatically. From that time until 11 October no adults were captured or seen at area I. After the appearance of juveniles at area II in early August, no adults were seen until 25 September when two frogs were observed but not captured.

Juvenile populations at area II did not appear to reach the density of the frogs at area I, and this may have been due to the weather. During the first week of June, the adult population was high and males were seen calling every 3-6 feet along the shoreline. On 15 June a heavy thunderstorm resulted in the creek overflowing its banks. The day after the storm, the cricket frog population was depressed, and only two frogs were captured along the entire length of the stream. Two weeks later only 10 frogs were captured after intensive searching along the stream. Two additional storms, one in July and one in August also caused the stream to flood although not as severely. Between the floods, there were dry periods and the stream ceasing to flow became a series of intermittent pools. Just as the floods may have swept adults, tadpoles, and eggs downstream, the lack of water during the dry periods may have limited the survival of some of the frogs trapped between pools.

A review of the 1972 sampling period is shown by Figure 1 which also shows a comparison of frog size for each month. Adults were captured from April through July and again in October, and juveniles were found from August through October. As the year progressed and as the frogs grew, the difference in snout-vent length (SVL) between the males and females became significant. In April there was no significant difference between sexes at the 95% confidence level, but in June and July females were significantly larger than the males; June, both males and females were significantly larger than the specimens captured in April. By October the frogs again approximated the size of the April specimens. The maximum SVL for April, June, and October specimens were 29.3, 33.4, and 27.9 mm, respectively.

<u>Food consumption</u>. As expected, it was found that the volume of the insects consumed increased with frog size. Figure 2 shows that as much as 0.31 g of food was present in the largest frog examined and that no more than 0.06 g of food was present in frogs 20 mm long or less. The stomach contents of juvenile cricket frogs weighed very little in August, but

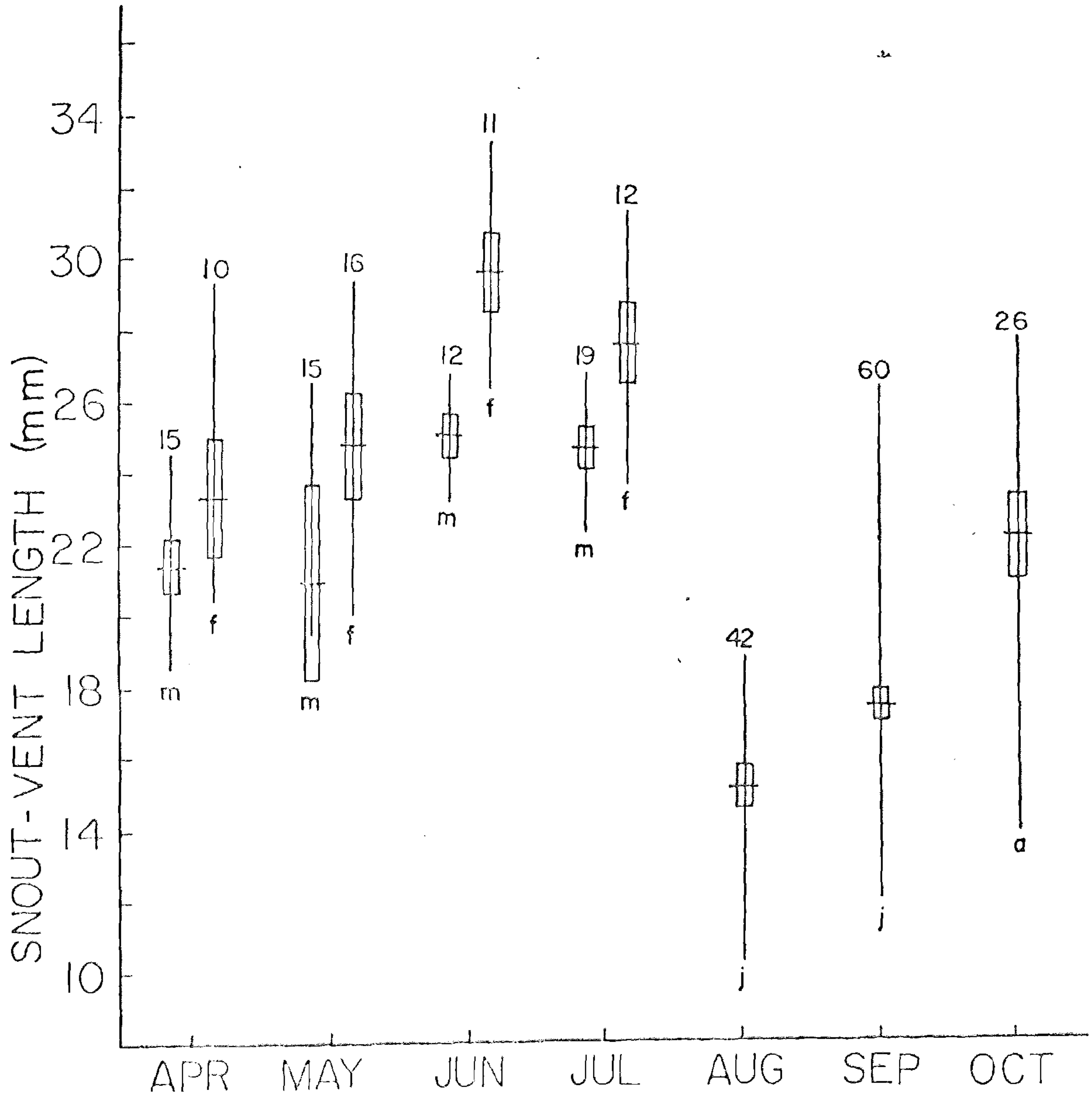

Figure 1. Monthly variation in snout-vent length for A. c. blanchardi from Iowa. Horizontal lines = means; rectangles = 95% confidence limits; vertical lines = ranges; numerals = sample size; letters in diagram indicate male (m), female (f), juvenile (j), and adult (a).

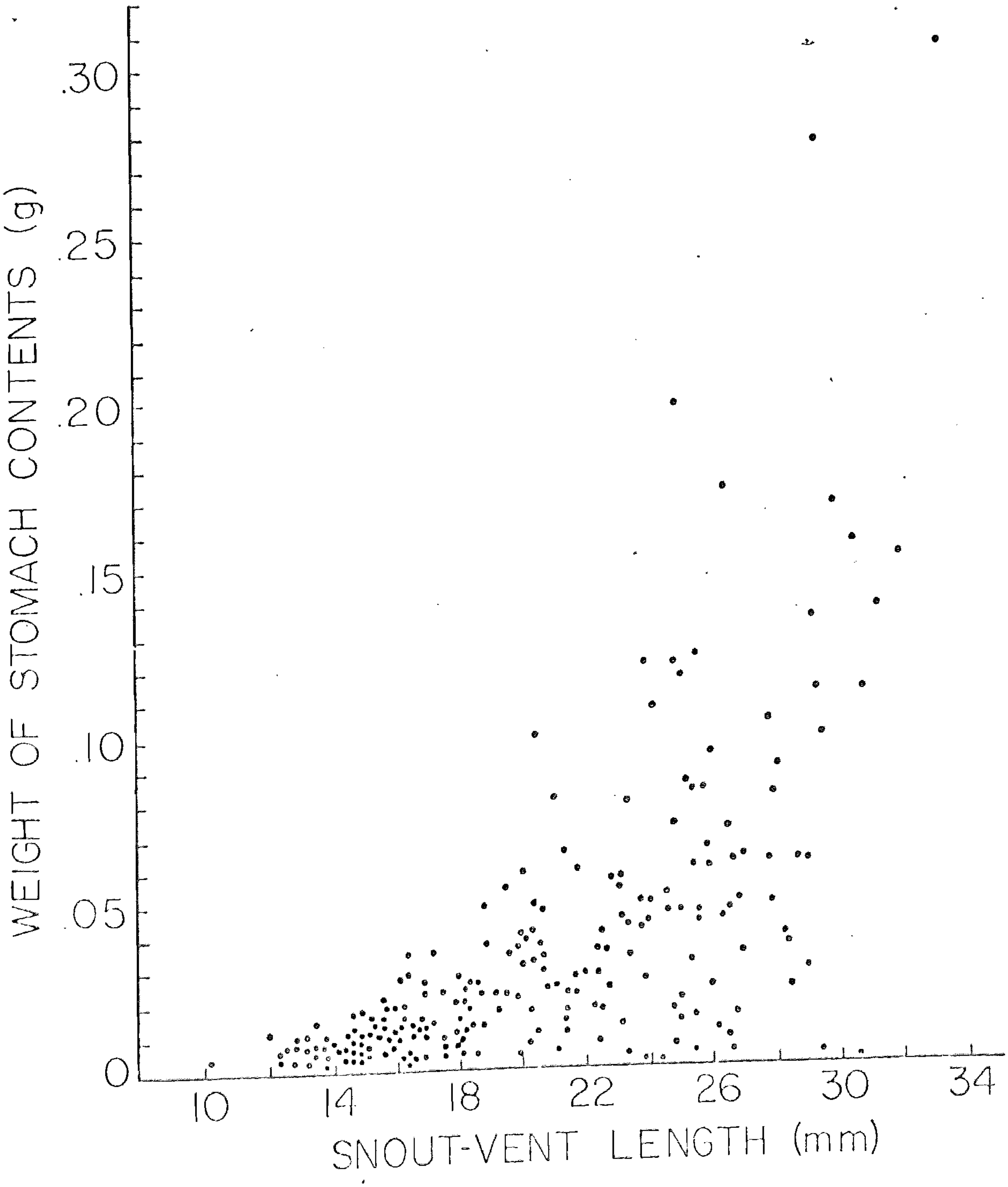

Figure 2. Correlation between snout-vent length and weight of stomach contents in A. c. blanchardi from Iowa.

by September this had increased to almost the April mean and paralleled an increase in frog size (see Figure 3). The October mean was very low possibly because these frogs were captured late in the month (27 October) following three days of cold weather. The area had subfreezing temperatures and snow earlier in the month (20 October) possibly depressing the insect population and therefore the major food supply of the frogs.

Of the 218 A. crepitans sacrificed within five minutes of capture, time zero, only 4 had empty stomachs. An analysis of the food items found in the stomachs of 214 cricket frogs was made, tabulated, and presented in Table 1. It gives the number of stomachs containing a type of food item, percentage of stomachs containing the item (frequency of occurrence), total number of items in all the stomachs, and the percentage that each group contributed to the total volume of the stomach contents. Members of the phyla Annelida, Mollusca, and Arthropoda were identified. Annelids and molluscs contributed a combined total of only 1.0% volume of the stomach contents. Plants and inorganic material added 1.4% to the volume of the stomach contents. Arthropods made up the remainder of the volume (97.6%). Four classes of arthropods were found, Chilopoda, Crustacea, Arachnida, and Insecta, contributing 0.2%, 1.0%, 10.7%, and 85.7%, respectively, to the volume of the stomach contents. Insects and arachnids were the major food sources for the frogs. The percentage volume of stomach

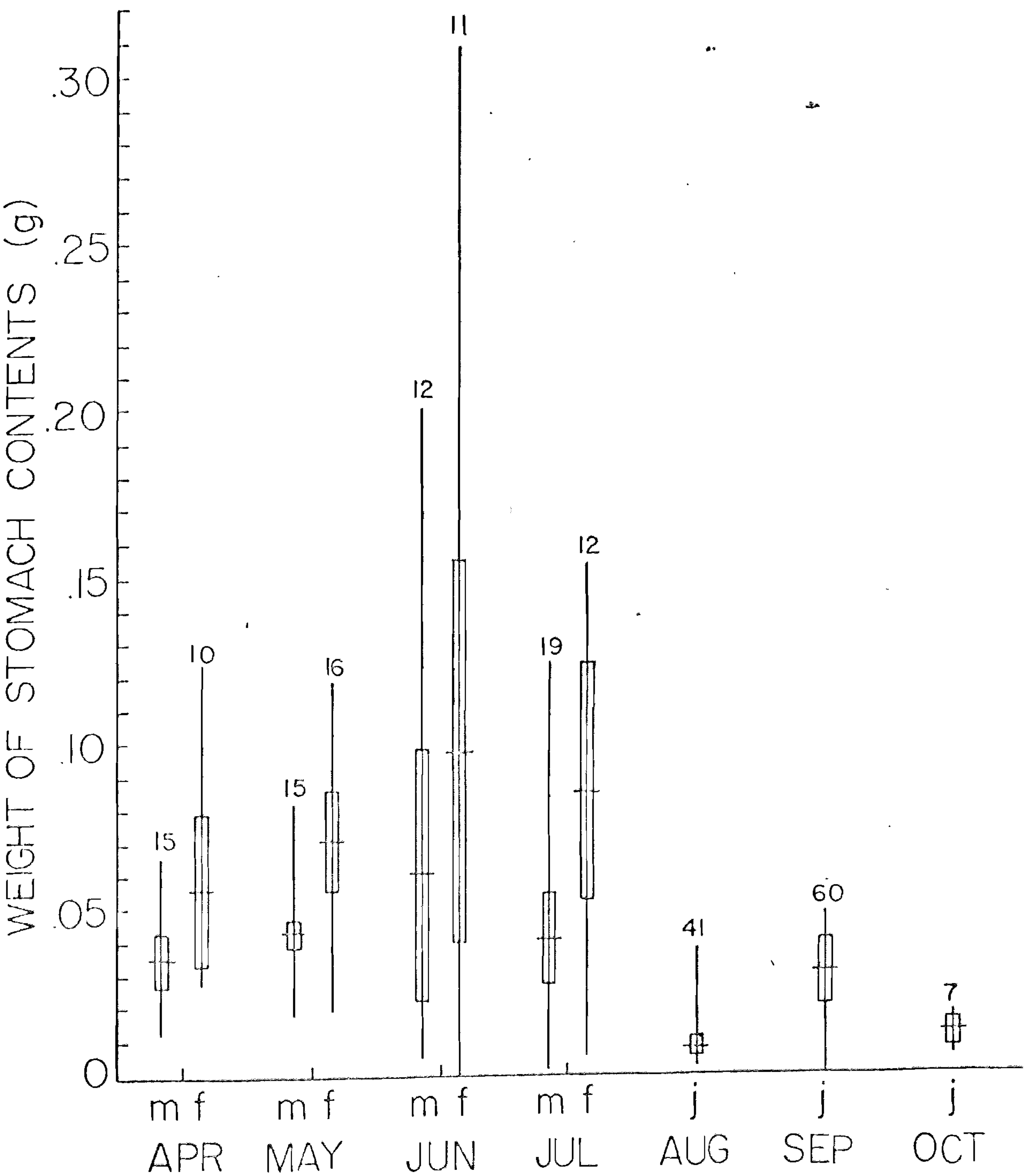

Figure 3. Monthly variation in weight of stomach contents between male (m), female (f), and juvenile (j) _A. c. blanchardi_ from Iowa. Horizontal lines = means; rectangles = 95% confidence limits; vertical lines = ranges; numerals = sample size.

Table 1. An analysis of the food items found in the stomachs of 214 Acris crepitans blanchardi captured in Iowa. The number of stomachs containing a food item, percentage of stomachs containing the item, total number of items in all stomachs, and the percentage that each group contributes to the total volume of the stomach contents is given.

Food item	# stomachs containing item	% of stomachs containing item	Total # of item in all stomachs	% by volume
Annelida				
Oligochaeta	1	.5	1	.4
Mollusca				
Gastropoda	3	1.4	3	.6
Arthropoda				
Arachnida				
Acarina	25	11.7	31	.5
Araneae	58	27.1	84	9.7
Opiliones	2	.9	2	.5
Chilopoda	3	1.4	3	.2
Crustacea				
Isopoda	4	1.9	9	1.0
Insecta				
Coleoptera				
Carabidae	38	17.3	56	2.6
Cerambycidae	2	.9	2	.5
Chrysomelidae	6	2.8	9	1.5
Cleridae	2	.9	2	.6

Table 1. (Continued).

Food item	# stomachs containing item	% of stomachs containing item	Total # of item in all stomachs	% by volume
Coccinellidae	1	.5	1	.1
Curculionidae	16	7.5	19	2.0
Endomychidae	1	.5	1	.1
Heteroceridae	1	.5	1	.4
Histeridae	1	.5	1	.2
Scarabaeidae	2	.9	2	.1
Staphylinidae	4	1.9	8	.7
Unidentifiable	39	18.2	47	3.1
Collembola				
Entomobryidae	38	17.8	456	2.5
Poduridae	2	.9	2	.2
Diptera				
Agromyzidae	1	.5	1	.1
Calliphoridae	1	.5	2	.5
Ceratopogonidae	1	.5	1	.1
Conopidae	4	1.9	16	.6
Culicidae	2	.9	4	.1
Dolichopidae	5	2.3	5	.2
Drosophilidae	2	.9	2	.1
Lonchopteridae	1	.5	1	.1
Muscidae	5	2.3	5	1.5
Mycetophilidae	1	.5	1	.1

Table 1. (Continued).

Food item	# stomachs containing item	% of stomachs containing item	Total # of item in all stomachs	% by volume
Phoridae	5	2.3	5	.2
Phyllomyzidae	1	.5	1	.1
Pipunculidae	1	.5	1	.1
Sciomyzidae	5	2.3	8	1.5
Simuliidae	2	.9	2	.1
Syrphidae	25	11.7	29	5.8
Tachinidae	1	.5	1	.2
Tipulidae	1	.5	1	.2
Unidentifiable	63	29.5	80	8.6
Hemiptera				
Gerridae	2	.9	2	.9
Saldidae	6	2.8	9	1.1
Tingitidae	1	.5	1	.2
Unidentifiable	9	4.2	13	1.5
Homoptera				
Aphididae	46	21.5	235	4.7
Cicadellidae	47	22.0	61	5.5
Membracidae	2	.9	2	.1
Unidentifiable	3	1.4	4	.2
Hymenoptera				
Euroytonidae	1	.5	1	.1

Table 1. (Continued).

Food item	# stomachs containing item	% of stomachs containing item	Total # of item in all stomachs	% by volume
Formicidae	58	27.2	106	4.4
Halictidae	2	.9	2	.4
Scelionidae	1	.5	1	.1
Tenthredinidae	1	.5	1	.7
Tiphiidae	4	1.9	16	1.0
Unidentifiable	8	3.7	9	.7
Odonata				
Agrionidae	7	3.3	11	2.5
Coenagrionidae	2	.9	4	.6
Orthoptera				
Gryllidae	2	.9	7	.5
Locustidae	21	9.8	26	5.0
Protura				
Eosentomidae	2	.9	2	.1
Thysanura				
Lepismatidae	1	.5	1	.4
Trichoptera	1	.5	1	.1
Larvae	32	15.0	36	3.8
Insect debris	114	52.3	--	16.3
Plant matter	5	2.3	5	1.0
Inorganic material	4	1.9	--	.4

contents that each order of insects contributed to the diet were: Diptera 20.2%, Coeoptera 11.9%, Homoptera 10.5%, Hymenoptera 7.4%, Orthoptera 5.5%, Hemiptera 3.7%, larvae (Diptera, Coleoptera, and Lepidoptera) 3.8%, Odonata 3.1%, Collembola 2.7%, miscellaneous groups 0.6%, and insect debris 16.3%. Of the 10.7% volume contributed by arachnids, Araneae (spiders) contributed 9.7%; Ararina (mites) and Opiliones (harvestmen) each contributed 0.5% to the total volume. No shed frog skins were found in any stomach.

Probably both the size of the frogs and the size of the insects available influenced the size of the food items consumed. Smaller Acris ate smaller items. The largest frogs were captured in June, and during this month the percentage frequency of Orthoptera (Figure 4) and Araneae (Figure 5) consumed were highest. Odonata were only consumed during June and July, and these three taxonomic groups represented the largest organisms consumed by the frogs. Damselflies (Odonata) were the largest insects consumed and measured over 25 mm in length--longer than some of the frogs that ate them. The very small insects, e.g. Formicidae, Cicadellidae, and Aphididae, were not found in stomachs at all during June. In August and September when the frogs were the smallest, these three families were more frequent than at any other time (Figures 6-8, respectively). Diptera and Coleoptera were found in stomachs throughout the year in relatively high frequencies and were never below 25 and 17%, respectively (Figures 9-10).

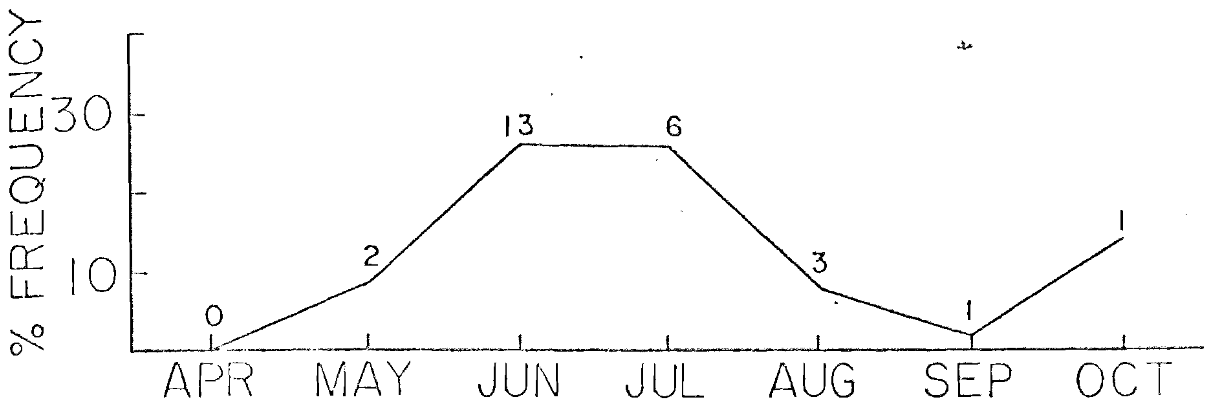

Figure 4. Monthly variation in frequency and number of Orthoptera consumed by A. c. blanchardi in Iowa. Lines in diagram = % frequency of Orthoptera consumed. Numerals in diagram = number consumed each month.

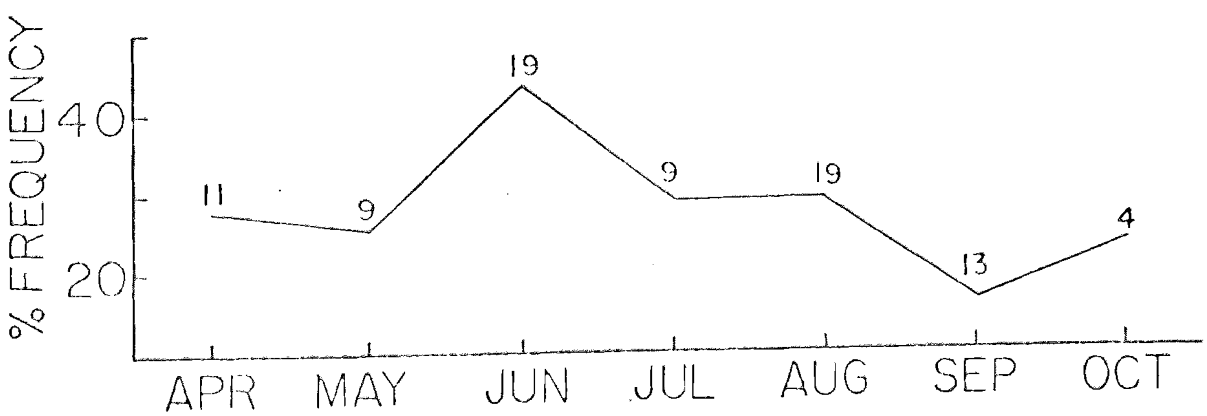

Figure 5. Monthly variation in frequency and number of Araneae consumed by A. c. blanchardi in Iowa. Lines in diagram = % frequency of Araneae consumed. Numerals in diagram = number consumed each month.

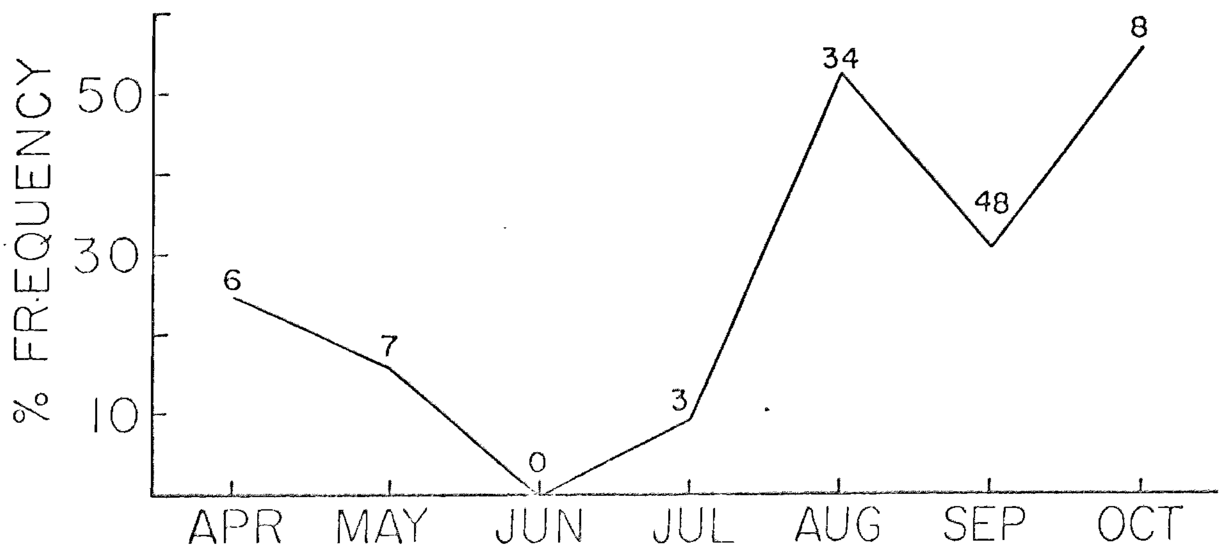

Figure 6. Monthly variation in frequency and number of Formicidae consumed by A. c. blanchardi in Iowa. Lines in diagram = % frequency of Coleoptera consumed. Numerals in diagram = number consumed each month.

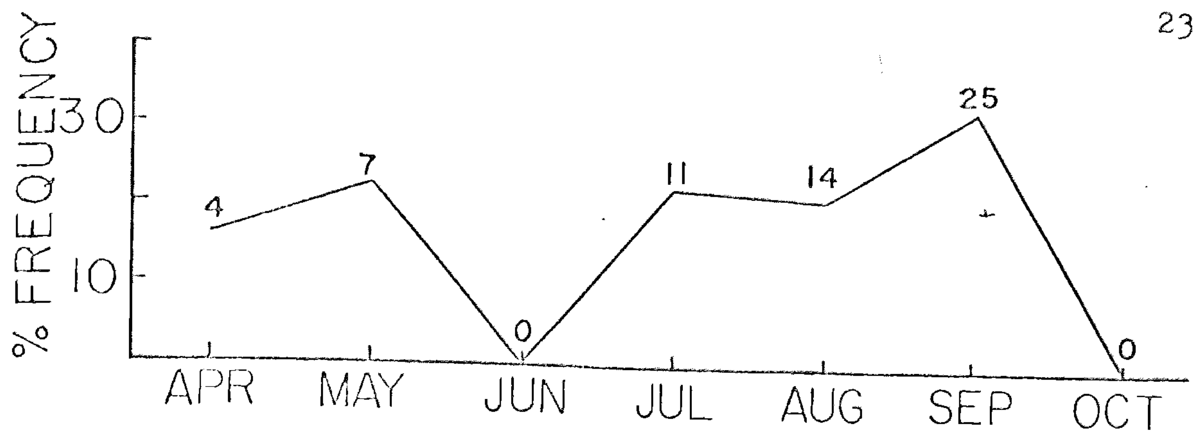

Figure 7. Monthly variation in frequency and number of Cicadellidae consumed by A. c. blanchardi in Iowa. Lines in diagram = % frequency of Cicadellidae consumed. Numerals in diagram = number consumed each month.

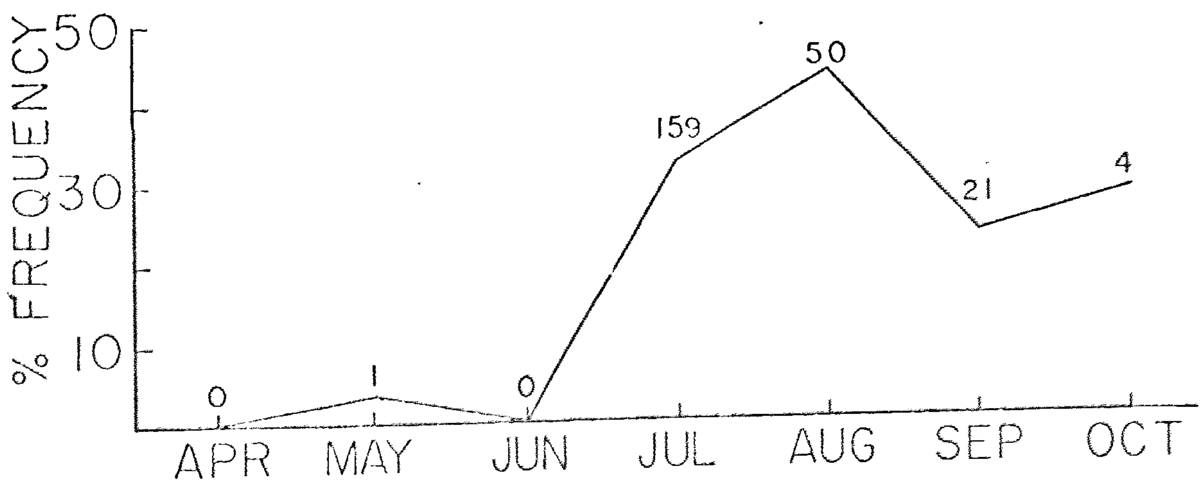

Figure 8. Monthly variation in frequency and number of Aphididae consumed by A. c. blanchardi in Iowa. Lines in diagram = % frequency of Aphididae consumed. Numerals in diagram = number consumed each month.

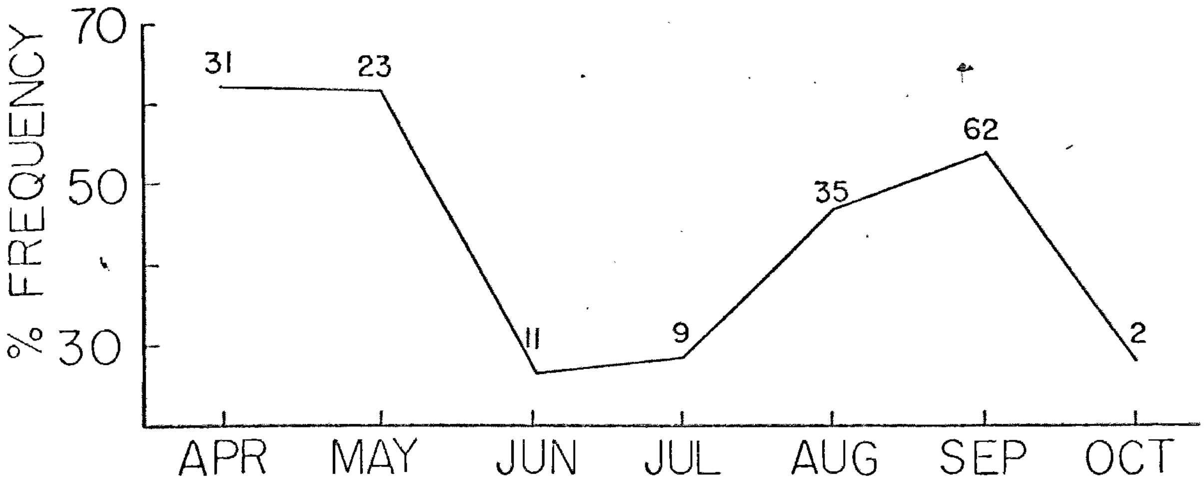

Figure 9. Monthly variations in frequency and numbers of Diptera consumed by A. c. blanchardi in Iowa. Lines in diagram = % frequency of Diptera consumed. Numerals in diagram = numbers consumed each month.

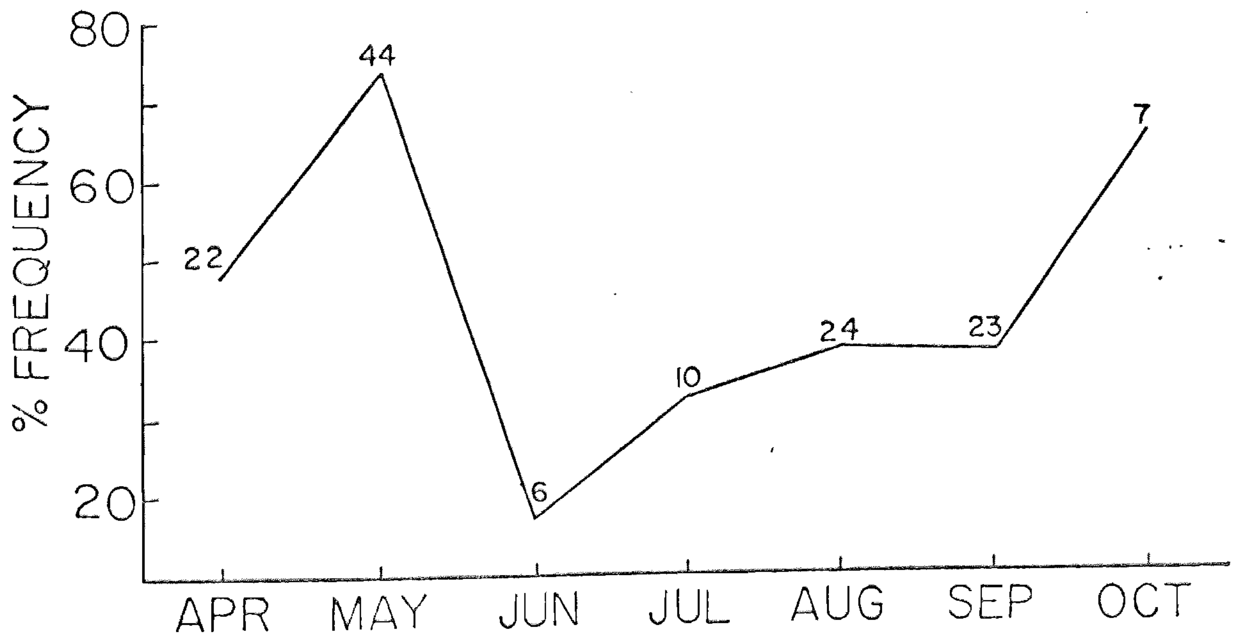

Figure 10. Monthly variation in frequency and number of Coleoptera consumed by A. c. blanchardi in Iowa. Lines in diagram = % frequency of Coleoptera consumed. Numerals in diagram = number consumed each month.

These two orders of insects represented a constant food source for the frogs.

The following observations show that insect life cycles also affected the diet of the cricket frogs. Insect larvae, mostly Coleoptera and Lepidoptera, supplied 3.8% of the volume of the stomach contents. A total of 27 Coleoptera larvae and 8 Lepidoptera larvae were consumed. Only one dipteran larva was identified. Lepidopteran larvae were consumed only from April through July. Coleoptera larvae were consumed sporadically from April through July. In September, a large number of small Coleoptera larvae were consumed (less than 2 mm in length), but in August a variety of different sized coleopteran larvae were found. Small instars of Orthoptera (Locustidae) and other insects were present in high numbers during June and July. The large size of the adult <u>Acris</u> at this time permitted consumption of these insects (Figure 4). Within a few weeks, the same insect species were much too large for the juveniles to eat.

Unidentifiable insect debris was found in 53% of the stomachs and consisted of broken exoskeletons, appendages, and nearly digested insect bodies. These were digested to a point where it was no longer possible to identify them to order. This debris comprised 16.3% of the stomach contents by volume. The remainder of the volume of the stomach contents was composed of inorganic material (0.4%) and plant material (1.0%).

Demand for food at different times of the year may have been affected by several factors in addition to growth and activity cycle such as the reproductive cycle and fat body production. As the SVL increased, the weight of stomach contents (WSC) also increased (see Figure 2), but the ratio between WSC and SVL did not remain constant (see Table 2). For adults, the ratio increased from April through June but decreased sharply in July. For juveniles the ratio was smallest in August and then increased in September. The October ratio was not calculated because of the small sample size. Brenner (1969) found that the reproductive cycle was marked by peak egg laying at the end of May and peak Leydig cell activity in the middle of May for _A. crepitans_ from Pennsylvania. Wright and Wright (1949) reported _Acris_ breeding on 12 June 1926 near Ames, Iowa, and Livezey (1950) stated that the breeding season for _Acris_ was from the latter part of April to the end of July depending on the latitude. In the present study, egg masses appeared smallest in early April (mean of 2.0 x 3.4 mm). In May they increased to a mean size of 4.4 x 7.8 mm, and by June, the mean size increased to 6.5 x 12.2 mm. The July mean decreased to 4.4 x 8.7 mm reflecting the laying of eggs by approximately 50% of the females. Males began calling on 15 May but as eggs were fertilized, calling decreased and no calls were heard after 25 July. The size of egg masses correlated directly with the ratios between WSC and SVL.

Maximum utilization of fat bodies occurred during

Table 2. Ratio of weight of stomach contents to snout-vent length of *Acris crepitans blanchardi* from Iowa. Male = m; Female = f; Juvenile = j.

	SVL (mm)			WSC (mg)			SVL/WSC		
Month	m	f	j	m	f	j	m	f	j
April	21.4	23.3	--	35	56	--	1.45	2.40	--
May	21.0	24.8	--	43	71	--	2.05	2.86	--
June	25.1	29.7	--	61	98	--	2.43	3.30	--
July	24.8	27.7	--	41	76	--	1.65	2.74	--
August	--	--	15.2	--	--	8	--	--	0.53
September	--	--	17.5	--	--	31	--	--	1.77

breeding and hibernation (Brenner, 1969). In this study, fat bodies were very small (less than 2 mm long) in juvenile frogs in August. The largest fat bodies were found in September and October specimens and were 7-8 mm long with many anterior projections. April specimens had small, slender fat bodies approximately 3-4 mm long. In May fat bodies had increased in size but were smaller than the October size. By the end of June and into July, most of the fat bodies were again very small.

Rate of food passage. The rate of food passage **from** the stomach of *Acris* was determined from three experiments. The first of these was a preliminary experiment conducted on 22 August when 49 frogs were captured and transported from area I to Drake University, a total of 17 miles, and placed in a laboratory cage. The insect free cage used was a one-gallon polyethylene bottle, certainly a highly unnatural and restrictive environment. Each hour for seven hours, seven frogs were sacrificed and analyzed for determination of the rate of digestion of the and passage of the stomach contents. It was found that the weight of the stomach contents did not decrease constantly but in an irregular pattern.

Because of the irregular results from the first experiment, an insect-free outdoor cage was constructed in the frog's natural environment for a second experiment at area I. For this experiment 63 frogs were used. Additional frogs (15) were captured and sacrificed on the preceeding day to give a better approximation of the amount of food in stomachs of freshly captured frogs. These frogs were lumped with the frogs that were sacrificed at time zero. Of the 63 frogs captured, 16 were sacrificed within one hour of time zero; the remaining 47 frogs were sacrificed, 7 each hour, and preserved except for 1200 hours when none were sacrificed. At 1900 hours, the remaining 5 frogs were sacrificed. The total time expended without food for the latter frogs was nine hours. Stomach contents were weighed and analyzed in the laboratory, and the results were plotted in Figure 11. There was a continual decrease in the mean weight of the stomach contents for each time interval from 0.010 g at time zero to 0.002 g after nine hours of fasting.

It is apparent from Figure 11 that although the means for each sample decreased in a regular manner, there was considerable variation in the ranges. The wide range in the samples for 1500-1600 hours and 1700-1800 hours resulted from a single frog in each sample. Removal of these frogs would have reduced the upper limits of the ranges from 0.024 to 0.008 g for the 1500-1600 hour sample and 0.033 to 0.004 g for the 1700-1800 hour sample and would have reduced the means from 0.004 to 0.003 g and 0.004 to 0.001 g respectively. A nearby identical cage serving as a control remained insect-free during the entire nine hour experiment. No insects were observed in the cage with the frogs during the entire period

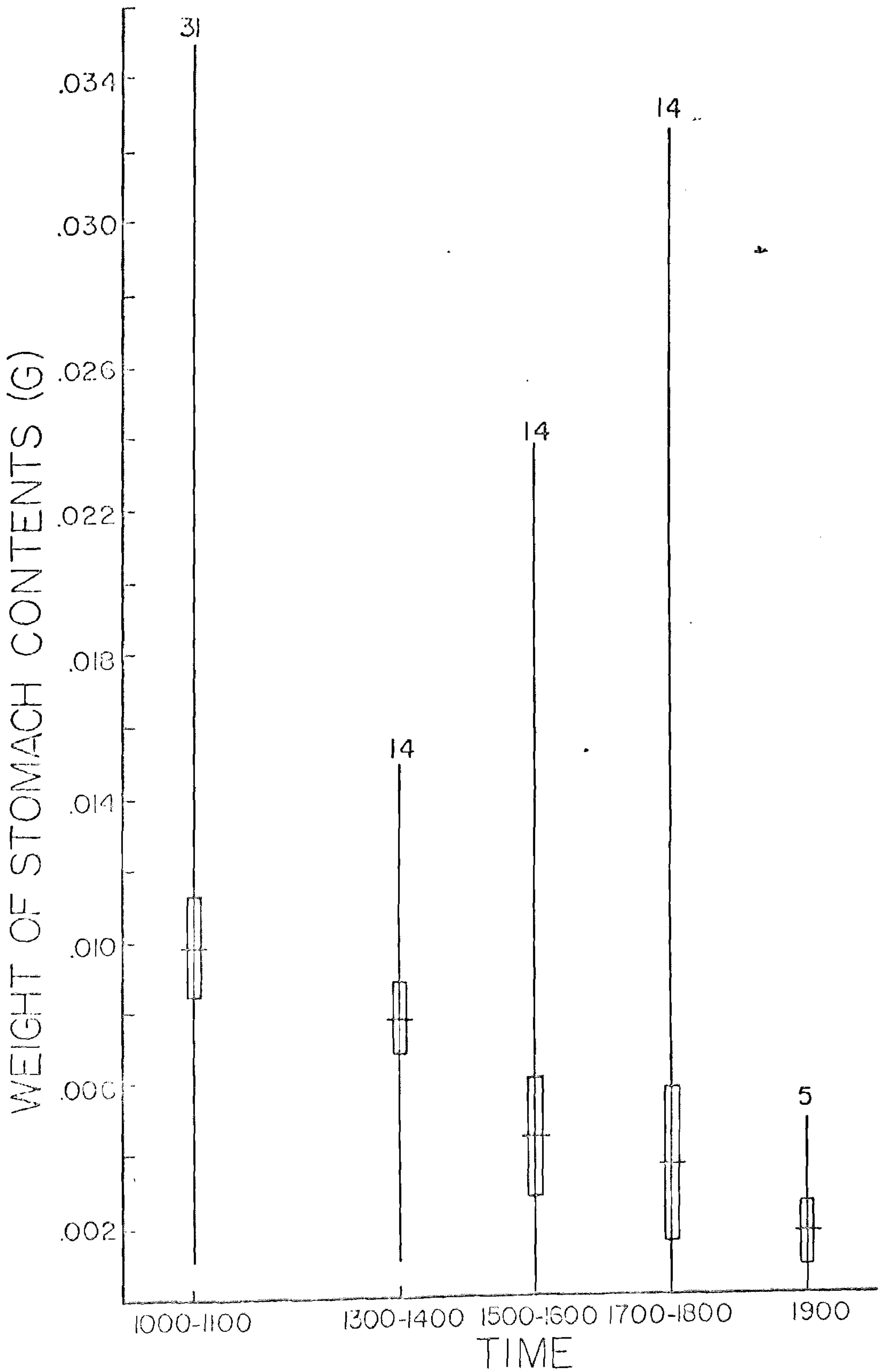

Figure 11. Decrease in the weight of stomach contents of frogs unable to feed with passage of time. Horizontal lines = means; rectangles = 95% confidence limits; vertical lines = ranges; numerals = sample size.

of the experiment.

In the third experiment 46 Drosophila melanogaster dyed with Kodack Opaque Red were force-fed to 46 cricket frogs at area II. These frogs were enclosed in a cage that was constructed on the stream bank to provide the frogs the optimal natural conditions to thermoregulate and feed on insects; the cages, in this case, were constructed to allow unrestricted entrance of insects. At 1530 hours on 10 October 1972, 15 frogs were placed in this cage for an overnight experiment. The frogs were sacrificed 17½ hours later, and it was found that the dye was either gone completely or concentrated in the cloaca. On 11 October, the same experiment was run from 0930 to 1730 hours. Of the 31 frogs force-fed dyed flies, 15 escaped through a hole in the cage and were not used, because it was felt that the chance of capturing a frog not fed a fruit fly was too great. Of the 16 remaining frogs, 3 were sacrificed five hours after feeding. Analysis showed that the Drosophila were in various states of decomposition in the stomach (broken or covered with mucus), but no dye was found in the intestines. Six Acris were sacrifieed two hours later. In one of these, the dye had moved into the intestines, but no dyed fruit flies were visible in the stomach. In four of the stomachs the dyed flies present had disintegrated or were barely held together by mucus. In the one remaining frog, the Drosophila had just begun to disintegrate. After a total of eight hours in the cage, the remaining 7 Acris were sacrificed. Dye could be seen in the intestinal tract of 4 of the frogs and none was present in the stomachs. In the fifth frog, the fruit fly was completely disintegrated and very hard to recognize, but the dye was still in the stomach. In the two remaining frogs, the Drosophila were not completely digested. One fly was covered with mucous and had started to break down. In the other frog the fly remained entire. These data indicate that most stomachs are emptied in eight hours after feeding.

Annual insect consumption. Frogs were captured and sacrificed at various times of the day and night and at no time was there any evidence to indicate that a significant number of Acris did not have food in their stomachs. The fact that only 4 of 218 or 1.8% of the frogs had empty stomachs indicated that the frogs ate constantly. From the results of the experiments conducted at area I and II, it can be concluded that it took an average of eight hours for food items to pass through the stomach. Therefore each day the A. crepitans found in south-central Iowa consume enough food items to fill their stomachs every eight hours.

A total of 1,456 food items were identified from the 218 cricket frogs for an average of 6.74 items per frog. This total only included items identified as far as order and excluded unidentifiable insect debris. The turnover rate of stomach contents was three times daily. Therefore, the frogs consumed an average of 20.2 food items per frog per day.

Assuming that the frogs were active 240 days (1 April to 1 November) in south-central Iowa, one frog could consume 4,840 food items per year. Table 3 shows the total number of food items identified, the percentage each group contributed to the total volume, and the total number of items one frog would consume in one year or activity cycle.

Collembola contributed the most in numbers (1515), although this taxonomic group only contributed 2.7% of the total volume of the stomach contents. The large number of Collembola found was influenced largely by two cricket frogs with 217 and 169 springtails in their stomachs. Jameson (1947) reported over 200 springtails in one cricket frog in his work. The specific location (someplace in Kansas or Nebraska) and the date of capture were not given for that frog. Homoptera contributed 20.6% of the total number of items identified, and the two families Aphididae and Cicadellidae contributed 776 (16.0%) and 205 (4.2%) organisms, respectively, to the diet of one frog each year. A total of 174 dipterans were identified or 547 (11.3%) were consumed by one frog per year; of this, 16% were Syrphidae. Of the 149 Coleoptera identified (504 per frog per year), 56 were small carabid beetles less than 2 mm long. Of the 136 Hymenoptera identified, 78% were Formicidae of which 72 were less than 2 mm long. Coleopteran and lepidopteran larvae contributed 2.5% of the total number of organisms identified in the stomachs or 92 and 26 per frog per year, respectively.

Table 3. Food items consumed by <u>Acris</u> <u>crepitans</u> <u>blanchardi</u> from Iowa in one year.

Taxonomic group	Number of items identified	% of total number of items	Number of items consumed per year per frog	% by volume
ARACHNIDA	117	8.0	387	10.7
Acarina	31		104	
Araneae	84		278	
INSECTA	1348	92.0	4453	71.6
Collembola	458	31.3	1515	2.7
Homoptera	302	20.6	997	10.5
Aphididae	235		776	
Cicadellidae	61		205	
Diptera	174	11.3	547	20.2
Coleoptera	149	10.4	504	11.9
Hymenoptera	136	9.5	460	7.4
Orthoptera	33	2.3	111	5.5
Larvae	36	2.5	121	3.8
Hemiptera	25	1.7	82	3.7
Odonata	15	1.0	48	3.1
Miscellaneous	21	2.5	68	2.8
Inorganic Debris	--	--	--	0.4
Plant Material	--	--	--	1.0
Insect Debris	--	--	--	16.3
TOTAL	1456	100.0	4840	100.0

Several horticultural and agricultural pests were consumed by _A. crepitans_ during the year. Some of the pests and the numbers consumed by a typical frog were: Aphididae 776, Cicadellidae 205, larvae 121, Orthoptera 111 and several miscellaneous families of Coleoptera (Curculionidae and Chyrsomelidae) and Diptera (Syrphidae).

DISCUSSION

Annual activity cycle. A review of the annual growth cycle for cricket frogs shows that froglets were first observed on 1 August. The frogs increased in size from a mean SVL of 15.2 mm in August to a mean length of 22.5 mm by October. In this month the frogs were approximately the same length as those captured in April. Frogs captured in June and July had continued growing and were significantly larger than the April specimens. There was only one specimen from April with a SVL greater than 25.8 mm (see Figure 1). No adults were seen or captured at area I after the emergence of froglets. The failure to obtain adults may have been for three reasons. First, one might suspect that the adult cricket frog population was depressed because of repeated sampling or because of natural predators including _Rana catesbiana_, _Thomnophis surtalis_, _Natrix sepidon_, and _Aves herodias_. However when the last July sample was taken, the frog population appeared to be nearly as large as earlier in June and July. Secondly, all frogs were collected randomly, there being no attempt to select for either sex or age group. The tremendous number of juveniles present in August and September made it unlikely that any frogs captured would be of the remaining adults. Estivation of adults might be a third contribution to the decrease in the adult population. However, fat bodies in adults captured in July were not as large as those found in frogs in October indicating that the frogs had not stored a large amount of energy.

The inability to capture adults in August and September and the statistically significant difference in SVL between the April sample and those from the June and July samples strongly support the hypothesis that the vast majority of adults die between July and emergence from hibernation the following spring. Possibly a very few large July adults manage to estivate through August and September and emerge the following spring after hibernation, but there is no evidence of the large frogs in the April sample. Note maximum frog sizes in April, June, and October for males, females, and juveniles in Figure 1.

The reproductive cycle and food consumption were closely related. Egg masses were the smallest in April and increased to their largest size in June. From the data on the size of egg masses, it appeared that the height of the breeding season was in June, and that by July many of the females had laid their eggs. The correlation between the reproductive cycle and food consumption was that as the eggs enlarged, there was a greater demand for energy, hence food consumption increased at a greater rate than the growth rate. Near the end of the breeding season, the demand for food decreased, and the corresponding decrease in the ratio of WSC to SVL was seen (see Table 2). The monthly ratios between WSC and SVL were important in that they showed the relative amounts of food being consumed by the frogs regardless of size.

Cyclic utilization of fat bodies can be correlated with hibernation and reproduction. From August through October, the subadults had to accumulate enough energy as fat, in addition to the energy needed for growth, to survive hibernation. After emergence from hibernation, the fat bodies were small but increased in size in April and the first half of May. During the height of the breeding season, the fat bodies were very small. Brenner (1969) found that the fat bodies in *Acris* decreased in size during the breeding season and proposed that the decrease may have been due to either an increased energy requirement of the population or a decrease of food consumption during breeding. The data collected in this experiment supported the idea that there was an increase in the energy requirement. Therefore, the decrease in the size of the fat bodies and the increase in the weight of stomach contents during the breeding season was probably a result of the increased energy demand for the production of gametes and courtship by the frog population. The weight of stomach contents in July decreased approximately 17% or 0.015 g from the June mean. Although not significant at the 95% confidence level, the decrease may reflect a completion of the breeding season and a corresponding decrease in energy requirements.

Diet of Anurans. Food consumption by cricket frogs was influenced by the activity cycle of the frogs and by the habitat in which the frogs foraged. Collecting sites in this study were pond and stream communities. Vegetation along the shoreline varied from dense grass and cattails to barren gravel shores. Most frogs were initially seen on land within one or two feet from the shoreline, although some were captured as far as 10 feet away from the water. Few frogs were seen initially in the water or on floating vegetation, but when frightened, the frogs often jumped into the water and then swam back to the shore. Of the arachnids and insects identified in the stomach contents, a vast majority of them were terrestrial organisms.

Various authors have studied diets of *Acris* and have reported conflicting results with respect to the source of the food supply. Garman (1892) stated that the diet of the cricket frog was mostly aquatic insects, while Hartman (1906), reporting on the stomach contents of seven frogs, decided that terrestrial insects constituted the bulk of the diet. Jameson (1947) concluded that *A. crepitans* consumed "mostly aquatic insects many of which were bottom dwellers." He found that Coleoptera contributed 54.6%, Arachnidia 23.8%, and Diptera 11.9% of the volume of the stomach contents. Jameson stated that the larvae of water beetles was the most common Coleoptera found, and a majority of dipterans were midge larvae. In the present study, the aquatic insects found were mostly Hemipterans. The percentage of bulk of the diet that larvae contributed to the stomach contents was not given by Jameson (1947) but must have been considerably higher than the 3.8% found in this study. Jameson's results might have been affected by seasonal variations in climatic conditions. He collected specimens from 3 March to 14 April and again in October from sites in Kansas and Nebraska. These periods may have been before or after most adult insects were active possibly forcing the frogs to forage on insects found in strictly aquatic habitats.

Gehlback and Collette (1959) examined eight _A_. _crepitans_ and found that "two contained carabids, two contained pyralid larva, and one each contained mirids and small spiders." This study was too limited and did not add much to the knowledge of the diet of this frog. Duellman and Schwartz (1958) examined 36 _A_. _gryllus_ _dorsalis_ from Florida and found that Coleoptera followed by Formicidae contributed most to the bulk of the diet.

The results of the present study compared with work done on other species of anurans showed that cricket frog diet was not similar to anurans of the same size when the habitats were comparable but different for anurans with less similar habitats. Cricket frogs and *Rana pipiens* were found together along stream and pool shores. Whitaker (1961) and Linzey (1967) studied the stomach contents of young or immature *R. pipiens*. Linzey worked with immature frogs 20-35 mm long and found that insect larvae contributed 10.9%, vegetable matter 11.8%, Coleoptera 29.3%, Hymenoptera 8.4%, Homoptera 8.1%, Orthoptera 6.0%, Diptera 3.6%, Hemiptera 6.0%, arachnids 3.6%, and unidentifiable insect matter 9.5% of the volume of the stomach contents. Whitaker found that insect larvae contributed 15.4%, unidentifiable animal matter 10.0%, vegetable matter 8.9%, snails 8.0%, Coleoptera 12.6%, Orthoptera 10.7%, Diptera 6.5%, Hemiptera 5.8%, and Hymenoptera 5.8% of the volume of the stomach contents. Vegetable matter and insect larvae were two taxonomic groups that contributed much more in bulk to the diet of *R. pipiens* than that of *Acris* in the present study. Coleoptera contributed 11.9% of the volume of the stomach contents in *Acris* and from 12.6 to 29.3% in *R. pipiens*. Diptera, the major food source for the cricket frog in the present study (20.6% by volume) only contributed 3.6 and 6.5% volume in the two studies of *R. pipiens*. Although Homoptera, Hemiptera, and Hymenoptera were found in nearly the same percentage volume, a breakdown of the orders showed that different families comprised the bulk of the diet for frog. In studies of *R. pipiens* during breeding season, no frog was found to have an empty stomach or to have consumed shed skins (Linzey, 1967). Even though they were found in the same habitat, the food sources of R. pipiens and A. crepitans differed.

The numerous studies done on juvenile Bufo have shown that the diet of these toads to be comprised of insects and arachnids and that the diets differed dramatically from that of A. crepitans. Gehlback and Collette (1959) examined 13 B. woodhousi from Nebraska and found that Coleoptera contributed 63.5%, Hymenoptera 17.8%, Arachnida 1.9%, and Diptera 1.5% of the volume of the stomach contents. Over 50% of the beetles were carabids and most of the Hymenoptera were ants. In a much more thorough analysis of the stomach contents of four species of juvenile Bufo from Oklahoma, Smith and Bragg (1949) found that insects and arachnids made up the vast majority of the items consumed. Insects contributed 99.3% of the stomach contents in B. terrestris americanus; of this ants contributed 93.3% and 4.3% of the contents were Coleoptera. In juvenile B. woodhousi woodhousi arachnids contributed 13.1% and insects the remainder of the volume of the stomach contents. Insects broke down into the following taxonomic groups: Hymenoptera 29.5%, Diptera 11.5%, and Coleoptera 45.9% of which carabids contributed 42.6% of the volume of the stomach contents. In B. cognatus 60% of the volume of the stomach contents were arachnids and 40% insects. All the items identified in B. compactilis were insects, and of this, 75.4 were Formicidae.

Both Bush and Menhinick (1962), who examined B. woodhousi fowleri from Georgia, and Campbell (1970), who examined 33 B. boreas boreas stomachs from Colorado, found Hymenoptera and Coleoptera to occur at the highest frequency. From the results of these studies of the diet of Bufo, it was evident that Hymenoptera, Coleoptera, and Arachnida made up the majority of the stomach contents and all other taxonomic groups were nearly excluded. Even though the juvenile Bufo reported here were of the same size as Acris, the latter had much more cosmopolitan feeding habits.

Pseudacris t. triseriata, Hyla c. crucifer, and Acris crepitans blanchardi, hylid frogs of approximately the same size, have been found together in ponds during the breeding season, but later, the frogs have been found in different habitats. Whitaker (1971) studied the stomach contents of Pseudacris in Indiana and found that during the breeding season only 64.9% of the stomachs contained food. These frogs were sacrificed immediately after capture. Vegetation, spiders, shed frog skins, snails, and lepidopterous larvae contributed 14.8, 11.7, 11.8, 7.0, and 11.7% volume of the stomach contents, respectively, during the breeding season. During the non-breeding season, Whitaker reported that spiders and ants were the two most important food items found (19.0 and 10.2% volume, respectively), and that frog skins and vegetation were not found. From this information, it can be concluded that when the two species, Pseudacris and Acris, are found together, they may rely on different animals for energy sources. Oplinger (1967) found that except for shed skins *Hyla c. crucifer* stomachs were always empty during breeding season. Although there is no proof for this, it could indicate that there is competition for food between small hylid frogs during the breeding season.

Shed frog skins were not found in any of the stomachs examined in this study or other studies of *Acris*. During the breeding season approximately 11% of the volume of the stomach contents of *Pseudacris* were shed skins (Whitaker, 1971). Oplinger (1967) found cast skins to be the most frequent food item in the stomach of *Hyla* from March to May. Frost (1932) reported the same phenomenon in peepers which were collected in the spring and suggested that frogs ate their first molt in the absence of more nutritious food. There appeared to be an inverse relationship between the amount of food consumed during the breeding season and the ingestion of cast skins. *Acris* fed constantly after emerging from hibernation and no skins were found, whereas *H. crucifer* did not eat during breeding season and shed skins were the major constituent of the stomachs. This may be of survival value for all the hylid frogs involved, because it may enable all three species to occupy the same breeding pond when food may be limited.

There appeared to be a direct correlation between the size of the frog and the size of food items identified in the stomach. Bragg (1958) found that selectivity as to size of food objects was a common phenomenon in several species of Bufo and Scaphiopus. As toads reached adult size, they paid little attention to small objects. Sweetman (1944) observed that captive Hyla versicolor which had gained some size and had eaten larger flies refused to feed on smaller fruit flies. Heatwole and Heatwole (1968) studied several species of toads and found a positive correlation between food size and toad size. Turner (1959) found that small Rana p. pretiosa ate only small prey, but larger frogs consumed items of considerable range in size. Oplinger (1967) found the same relationship between frog size and food item in Hyla crucifer. The present study supports the evidence for this relationship among anurans.

Opportunistic feeders. From the results of the present study and from the works of Garman (1892), Hartman (1906), Jameson (1947), Duellman and Schwartz (1958), and Gehlback and Collette (1959) it is evident that cricket frogs are opportunistic feeders and eat whatever animal of suitable size is available. Frogs from Iowa consumed mostly terrestrial insects and ate relatively few organisms found strictly in aquatic habitats. In general, it appeared that although Diptera and Coleoptera were fed upon by a significant percentage of frogs at all times, they formed a smaller percentage at times when other appropriately sized arthropods were more plentiful; this was most evident in June. The Diptera and Coleoptera seemed to act as a cushion, being always available and forming a substantial part of the diet, but giving way at intervals to other forms which became abundant for short periods. As these forms disappeared, the frogs tended to again focus their attention upon the Diptera and Coleoptera.

Metcalf (1921), Pack (1922), Smith and Bragg (1949), Hamilton (1955), and Bragg (1958) found that various species of *Bufo* were opportunistic feeders. Turner (1959), Jennsen (1967), and Linzey (1967) studied the seasonal diet of various species of *Rana* and found that these frogs were also opportunistic feeders. Oplinger (1967) and Whitaker and Myer (1971) worked with hylid frogs and concluded the same. Jameson (1956) noted that Hyla regalla fed *Drosophila* from culture bottles soon learned to sit on the bottle and wait for the flies to crawl out. These frogs learned to feed where the food was available. This would be a distinct advantage in nature. All in all, it can be stated that *A. crepitans* is similar to other anurans in its opportunistic feeding habits.

Rate of food passage. Little is known about the rate of food passage from the stomach of anurans, but all information available indicates that the rate varies from species to species depending on the activity cycle of the organism. In this study it was found that food passed from the stomach of the cricket frog within eight hours. Specimens were collected at various hours of the day, and at no time was there any indication that the frogs fed only during one period of the day. In the preliminary experiment run on 22 August, irregular results were obtained; this may have resulted from the handling, transporting, and caging of the frogs. In both the experiments run at area I and II, two frogs did not digest their stomach contents as fast as the rest of the frogs in the experiments. One probable explanation for this observation is that these frogs may have been under stress from being handled and caged resulting in a decrease in the rate of digestion. Smith and Bragg (1949) made similar observations on the rate of food passage from stomachs of four species of Bufo. Toads placed in cloth bags still had many items in their stomachs after 24 hours, whereas unmolested toads collected just before their feeding period began had empty stomachs. Kirkland (1904) and Dickerson (1906) stated that the toad emptied its stomach four times daily. Smith and Bragg (1949) refuted this and said that adult toads filled their stomachs one time daily. They based their argument on the fact that adults captured during the afternoon and dusk had empty stomachs, but toads captured later at night had stomachs full of food. Subadults fed continually and filled their stomachs at least twice as often as adults. Savage (1962) found that tadpole Bufo fed continually and passed food through the digestive tract in as little as 4 hours. Oplinger (1967) found that Hyla crucifer young of the year had two feeding periods each day, but adults only fed in the evening. When he sampled in the morning and afternoon, the adult stomachs were empty indicating that H. crucifer passed food through the stomach in considerably less time than 24 hours. Frost (1932) found that laboratory caged Rana clamitans and R. sylvatica passed food through their digestive tracts in two to three days.

Economic importance of Acris crepitans. In this study adult frogs were not active the entire year but around 1 August there was a transition between an adult population only to a juvenile dominated population. Therefore the yearly consumption figure of 4,840 items consumed per frog per year represented a synthesis of the insect consumption of the adult and juvenile populations, or it represented the items consumed by a juvenile until hibernation and then the additional items it consumed following hibernation until the emergence of the new froglets. Since Acris fed indiscriminately upon carnivorous and phytophagous arthropods, it was obvious that the economic effect of their feeding habits would vary widely with changing habitats and ecological conditions. Under special conditions of insect outbreaks, frogs may be very effective in controlling insect pests (see Pack, 1922). Destruction of spiders by frogs may appreciably decrease the control these predaceous arachnids maintain upon insects (both destructive and beneficial). The eating of cicadellids, aphids, etc. is beneficial but destruction of damsel flies and spiders may offset this in some degree.

The families of Coleoptera that contributed to the greatest volume of the stomach contents were Carabidae (2.6%), Curculionidae (2.0%), and Chrysomelidae (1.5%). Carabids are predacious beetles, but Curculionidae adults and larvae feed on fruiting bodies of plants. Chrysomelidae also feed on plants and the larvae consume roots. The majority of the Collembola were in the family Entomobryidae. These organisms were found in moist places and were not a major economic pest. Syrphidae, Sciomyzidae, and Muscidae were the major dipteran families identified. Muscidae represents a health hazard, while Sciomzidae larvae are predacious on snails. Syrphidae feed exclusively on flowering plants and some larvae are pests of flower bulbs. Homoptera were some of the most important pests consumed by the cricket frogs. Aphididae and Cicadellidae are often destructive to certain crops, not only by direct damage caused by feeding, but also because they transmit many plant diseases. The majority of the hymenopterans identified were Formicidae and represent agricultural pests only when they consume large amounts of grain and grass areas. Locustidae were found in 9.8% of the frog stomachs. These insects represent serious agricultural pests. They along with the cicadellids consume and destroy large amounts of vegetation each year.

The cosmopolitan food habits of cricket frogs render them, on the whole, about neutral in economic importance, in about the same sense that insects, on the whole, may be said to be neutral; (i.e., they maintain a balance in the forms they feed upon). Under certain conditions brought about by man's agricultural practices and pesticide use, frogs are at times likely to be especially beneficial. Time, place, and conditions make the difference. In suitable habitat large populations of Acris have been found; Pyburn (1954) stated that to find more than 1000 individuals around a farm pond of one-acre were not unusual. The feeding of large numbers of frogs day after day cannot fail to be of some importance on insect populations in localized areas. Given the same conditions as in this study, populations of 1000 individuals could consume approximately 4.8 million insects per year.

SUMMARY AND CONCLUSIONS

Summary. Examination of the stomach contents of 218 cricket frogs, *Acris crepitans blanchardi* Harper, and analysis of the rate of food passage of an additional 122 cricket frogs from Iowa, interpreted on the background of cyclic activity of the frogs, forms the basis for analysis of the importance of these frogs as consumers of insects. Two types of field cages were used. One cage was constructed to remain insect-free during the entire experiment. Frogs were placed in the cage, sampled at hourly intervals, and weight of stomach contents recorded. The second method utilized a cage constructed so that insects could pass freely into the enclosure but not

letting the frogs escape. From these experiments, it was possible to determine the length of time it took for a food item to pass through the stomach. The techniques developed for determining the rate of food passage from the stomach can be applied to other studies of anurans. Utilization of field cages is necessary to keep unnatural condition at a minimum.

Conclusions. The following conclusions can be made relative to the cyclic activities of the cricket frog: (1) Cricket frogs in Iowa are active from early April to late October; (2) Choruses are heard from the middle of May until the end of July; (3) During June and July, the height of the breeding season, female frogs are significantly larger at the 95% confidence level than male frogs; (4) Adult frogs are not active in August and September and may have died or be in estivation; (5) Juveniles first appear in early August and by October are the same length as frogs in April; (6) Sex of frogs is important in determining amounts of food consumed, females eat more than males; (7) Young (small) frogs consume smaller food items than older (larger) frogs.

The following conclusions can be made relative to the types and numbers of insects consumed: (1) Arthropods constitute the bulk of the food eaten; (2) Insects far outnumber other animal groups, both in terms of numbers and bulk; (3) Diptera, Coleoptera, Homoptera, and Hymenoptera are groups of insects that contribute the greatest volume to the diet.

Collembola followed by Homoptera contribute the greatest numbers to the diet; (4) Arachnids, mostly spiders, form the greatest single item of non-insect food; (5) Food availability as opposed to selection within a particular food size category appears to be the principle factor determining what Acris eat. Seasonal differences in food objects eaten merely reflect the seasonal availability of the food objects; (6) Food items pass through the stomach in approximately eight hours; (7) All indications are that cricket frogs feed continually; (8) Cricket frogs fill their stomachs three times daily and consume an average of 20.2 food items per day; (9) The frogs consume an average of 4,840 food items per frog per year, hence when frog populations are large, they might be expected to have a significant effect on insect populations; (10) Agricultural pests consumed include members of the Aphididae, Cicadellidae, Curculionidae, Syrphidae, Locustidae, and Coleoptera and Lepidoptera larvae.

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